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LabVIEW Interface Concepts Used in NASA Scientific Investigations and Virtual Instruments

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SUMMARY

This article provides an overview of several software control applications developed for NASA using LabVIEW. The applications covered here include

- an Ultrasonic Measurement System for nondestructive evaluation of advanced structural materials, an X-ray Spectral Mapping System for characterizing the quality and uniformity of developing photon detector materials
- a Life Testing System for these same materials,
- and the instrument panel for an aircraft-mounted Cloud Absorption Radiometer that measures the light scattered by clouds in multiple spectral bands.

Many of the software interface concepts employed are explained. Panel layout and block diagram (code) strategies for each application are described. In particular, some of the more unique features of the applications' interfaces and source code are highlighted. This article assumes that the reader has a beginner-to-intermediate understanding of LabVIEW methods.

INTRODUCTION

LabVIEW has developed an enthusiastic following worldwide for physics applications, engineering test and measurement systems, and process control (Johnson, 1997). Numerous NASA scientists and engineers use the LabVIEW language as the basis for instrument control, data acquisition, display, and data storage operations (Baroth, et al., 1998; Buchanan et al., 1996; Huff, 1998; Lhota, 1998; Wilson, 1997). With recent releases, LabVIEW has evolved from an instrument control and data acquisition tool to a general-purpose software development system that can be employed for nearly any application. Additionally, the ability to interface LabVIEW source code and applications with other programming languages (such as Visual Basic) means the software engineer can employ a combination of favorite tools and development environments while working on any project. Moreover, text-based

coding is still easily possible in LabVIEW through various types of formula nodes and script languages (such as MATLAB). In this article, several of the specific LabVIEW user interface concepts developed for NASA experimental applications are described. This article assumes that the reader has a beginner-to-intermediate understanding of LabVIEW methods.

Typically, a 'complete' application encompasses control, data acquisition, display, analysis, and data storage. The front panel layout and block diagram (code) strategies are given for each application. Some of the more unique features of the applications' interfaces are highlighted. The applications described here include an Ultrasonic Measurement System for nondestructive evaluation of advanced structural materials, an Xray Spectral Mapping System for characterizing the quality and uniformity of developing photon detector materials, a Life Testing System for these same materials, and the instrument panel for an aircraft-mounted Cloud Absorption Radiometer that measures light scattered by clouds in multiple spectral bands. All software was written for standard PCs running Microsoft Windows 9x/2000/NT operating and LabVIEW version 4 to version 6i.

NASA LabVIEW-BASED APPLICATIONS

Ultrasonic Measurement System For Nondestructive Evaluation of Advanced Structural Materials

The LabVIEW-based ultrasonic measurement system was designed to facilitate high-frequency (1 to 150 MHz) ultrasonic characterization of the internal structure of materials. Current materials the system is characterizing include those being developed for advanced high-temperature aeropropulsion applications under supervision of NASA. The velocity and attenuation of ultrasonic waves are dependent upon both material type (chemical composition) and microstructure (number of voids/pores, grain size). Since material microstructure impacts physical properties (for example, stiffness, strength, electrical conduction and so forth, ultrasonic measurements can to some extent be used to predict the behavior of materials in service.

The ultrasonic measurement system works as follows. A piezoelectric-based ultrasonic transducer is placed on top of the material sample to be characterized. The transducer is electrically excited by a voltage from a pulser and transforms the voltage into a high frequency mechanical wave (vibration). The wave is transmitted to and into the material sample where it bounces off of the sample surfaces. The various bounces or echoes return to the same transducer where they are converted from mechanical back to electrical form. The echoes are sent to a PC-based 1 GHz analog-to-digital (A/D) converter for digitization. The digitized waveform is output from the A/D converter for digital processing and display.

The LabVIEW program performs the major functions necessary to control the A/D converter (via a custom software driver). In addition, the software is responsible for analyzing the measurement data generated by the experiment, as well as displaying and storing the results of the analysis. Here, the software application and its most important subVI (subroutine) are described:

- The front panel was designed so that all functions necessary for full operation are clearly and easily accessible (fig. 1).
- The development team decided to forgo the conventional Windows gray-colored interface for a more colorful, but tasteful presentation.
- Function key navigation was employed for all control buttons (see F* notation on control buttons) to permit key stroke navigation in addition to mouse clicks.
- Menu and tool bars were selectively hidden using setup options.
- Help files and the underlying ultrasonic equations used for the ultrasonic properties calculations are accessible via windows activated from the front panel control buttons.

For the purposes of this article, a simulation/model of the software architecture has been constructed. The basic block diagram model employed for this application is shown in figure 2 and described below:

- The software architecture employed was a variation of the popular 'parallel while loop' concept (Johnson, 1997). By using this structure, two operations can execute concurrently. In this instance, continuous ultrasonic waveform acquisition occurs in the background (transparent to the user) within one while loop (the 'main' loop here), while other user-selectable subVI modules utilizing the waveforms are located in a second running while loop. SubVI modules are dynamically loaded using the 'Call by Reference' method. Although

only one subVI is shown in this model block diagram, each subVI resides within its own case structure and is dynamically loaded when the true case is activated.

- When the main VI is started, waveform acquisition begins immediately in the background and the waveforms are placed in a queue. When the user enters the various subVIs that require the live waveform feed, the waveforms are removed from the queue. In order to minimize memory usage, the queue is set up to hold only 1 waveform element. The 'insert queue element' function is set to timeout after 200 millisecond. The result of this setup is that if the user is not in a subVI which removes waveform elements from the queue, the queue is continuously emptied via a flush function. The timeout condition with flush function is necessary to prevent inefficient memory use and lockup of the main while loop (which would not allow stopping of the program).
- An array global variable was tested as a queuing system for exchanging the waveforms between main caller and the subVIs. However, the system seemed to run slower and choppy.

The OSCOPE subVI module is the heart of the ultrasonic measurement system and for the purposes of this article it has been updated to LabVIEW version 6i. Again, the front panel (fig. 3) has been designed for ease of use. This module allows frequency-domain analysis of time-domain waveforms and sends the frequency domain magnitude and phase outputs of the various echos (labeled B2, B1, FS2, FS1) in the waveform to the other modules for calculation of ultrasonic material properties. These ultrasonic material properties include Reflection Coefficient, Attenuation Coefficient, Cross-correlation Velocity, Phase velocity (Roth, 1995) and a number of other properties based on time- and frequency-domain characteristics. The OSCOPE module has the following characteristics:

- It is logically divided up into controls and indicators using vertical text labeling and grouping of front panel items.
- It has general and specific directions boxes in the front panel window that are highly visible to the user with the specific directions changing as different echoes are chosen.
- Tip strips are used to describe controls and indicators and provide direction for the user.
- User-adjustable controls are color-coded in order to differentiate them from indicators.
- Shows windows for time and frequency domain analysis of waveforms. The upper time domain waveform graph window shows the raw waveform and is voltage autoscaled. The lower time domain window shows a running average of the time domain waveform acquisition. All controls in the OSCOPE module are applicable to the running average waveform and not the raw waveform. The number of averages are user-selectable to any value in real-time, in both the time- and frequency-domains. (Signal-to-noise ratio is directly proportional to the square root of the number of averages). The time-domain running average technique is implemented via a modified circular buffer method (Johnson, 1997 and LabVIEW Developer Zone, 2000). AC coupling removes the DC component from the running average reducing spectral spreading. For best frequency domain results, voltage level should be adjusted for each (B2, B1, FS2, FS1) echo as it is time gated to obtain maximum height in the window without thresholding out.
- (The X-axis formatting of the graphs is in SI notation which shows 'u' for micro, 'n' for nano, etc. The X-axes labels show μsec as these are the time scales normally encountered in this ultrasonics research. This logic is also used in labeling the indicators to the lower right of the OSCOPE display window.)
- The use of real-time adjustable bubble cursors to define time windows for the individual echoes of the time domain waveform. These echoes are analyzed in the frequency domain window showing magnitude and phase. This frequency domain information is captured and stored for analysis of ultrasonic material properties as previously mentioned.
- The choice of frequency-domain windowing methods.
- Stopping of parallel loops from one control button (Johnson, 1997).

The block diagram of the OSCOPE module is shown in figure 4. Its characteristics include:

- Extensive use is made of control references so that property (formerly attribute) nodes of controls and indicators can be placed in subVIs. A property node new to LabVIEW version 6i, 'Value,' essentially eliminates the need for local variables. Therefore even initializations and other value changes can be handled in subVIs rather than on the block diagram where the control terminal is located. This results in a dramatic reduction in block diagram size and as such, will facilitate keeping block diagram size to a single nonscrollable panel (National Instruments, 2000).

- SubVIs are used to handle initialization, the modified circular buffer implementation, waveform display, cursor information, echo display, and frequency domain processing. These are the main functions of the module and by placing them in the block diagram, the user can get a general feel without having to go to lower levels of the flow and processes of the code. Diagram size and interpretation remains manageable. The diagram could have been reduced in size further (in terms of consolidation into more subVIs).
- LabVIEW version 6i 'waveform' functions are employed to build the waveform from the array and sampling information.
- Values that need to be recycled and/or are needed for comparison in order to make decisions are stored in shift registers attached to the while loop boundaries.
- Small 'wait' delays are placed in the while loops of the main diagram and in the while loop of the subVI module so no monopolizing of CPU time by any one module occurs.
- The architecture employed here allows the use of any A/D converter suitable for the requirements of the system.

Xray Spectral Mapping System For Characterizing The Quality And Uniformity of Photon Detector Materials

Development of longer-life and higher performance photon detector materials are needed for future Space and Earth science missions at NASA. These materials will be used to sense the different forms of radiation present in Space and in the atmosphere (Parker, et al., 1999). The facility described here (and the one described in the next section) should help in achieving these goals. The Xray Spectral Mapping system consists of two motorized manipulator stages which move a mounted photon detector sample relative to a 200 kV Xray tube (Xray photon source). The stages are moved by a PC-based motion controller board under LabVIEW supervision. The stages move in the lateral (X) and upward (Z) direction as the Xray tube bombards the photon detector sample under test with a collimated Xray beam at one spot (as small as 100 μm) on the sample. A voltage signal is generated across the sample related to the charge carrier lifetime and mobility of the sample at that X-Z scan location. The voltage signal is fed into a preamplifier before entering the PC-based multichannel analyzer A/D card for conversion to an Xray spectra. As a result of this process, an Xray spectra for each X-Z scan location is generated, and the uniformity of the sample with regards to charge carrier lifetime and mobility is mapped. Hundreds of images can be obtained in each scan since an image can be calculated at each channel.

The LabVIEW (version 5.1.1) software program developed for the system has the following characteristics:

- It utilizes a state machine architecture (Bitter, et al., 2001; Fowler, 1996; Gruggett 1995b; and Johnson, 1997) to efficiently handle the various main tasks. This results in the user being led through a series of menus for program options. Figure 5 shows the opening screen for the application.
- All instrumentation (multichannel analyzer A/D board, motion control system) is controlled via LabVIEW drivers.
- The following are used extensively throughout this application: significant numbers of shift registers to recirculate information, attribute nodes to control display attributes, and local variables for initialization and for operational control.
- Most of the subVIs corresponding to the main functions were dynamically loaded to reduce program footprint size in memory. The disadvantage to dynamic loading is the increased difficulty in debugging source code when all the functions are not in memory.
- Verbal (audio) directions can be enabled to help lead the user through the program. For this feature, .wav files were recorded and are played back via LabVIEW subVIs.
- Since hazardous radiation is used during the testing, a login feature is present as a safety feature to limit the users to only qualified and trained operators.
- Front panel control buttons are disabled at various times to guide the user through the proper program operation.
- A large front panel indicator shows messages alerting the user top program status.
- All controls and indicators have a description; the user can select the 'show help' menu item and view all descriptions during program operation. All subVIs in the block diagram have a description as well.
- The user has the option of displaying and analyzing data from the current scan, or from any previously-obtained scan data set.

- The advent of the tabbed menu interface in LabVIEW version 6i provides another user-friendly and popular interface choice for developers. The tabbed menu interface allows a state machine format in a potentially easier coding mode. This interface type was not used in this application since it was developed in LabVIEW v5.1.1.
- Development in LabVIEW v6i would also have allowed extensive reduction in block diagram sizes via the use of property nodes in separate subVIs. (A work of caution: check to make sure all software drivers are compatible with new versions of LabVIEW before upgrading a developed application.)

Figure 6(a) shows the panel for a subVI module used to view and analyze the Xray scan data. This module is quite powerful and has the following characteristics:

- The user has a choice of viewing one of three sets of images that were normalized/scaled in different fashions, all sets calculated after completion of scanning.
- An Xray spectrum (upper left plot window) is produced at each scan point which show photon counts versus channel or bin number. The bin numbers represent different Xray wavelengths or energy levels). The user is first asked to select a representative spectrum from one of the scan points. Thereafter, a scan image, or Xray map, appears in the top center plot window. The Xray map shows the Xray photon counts as a function of scan position at a particular bin number (with the bin number being that denoted by the cursor x location in the upper left plot window).
- Moving the cursor from left to right over the chosen spectrum in the upper left window, the image will change as a function of the bin number, and the user can cycle thru all the Xray maps in the data set.
- The Xray maps were computed from the spectra after the scan took place; all spectra and images were stored in binary files. The images were scaled in three different formats based on the minimum and maximum photon counts value of the individual image, the whole image set, or a series of image sets. Depending on data comparison objectives, the user can select which set of images to view.
- Just below these maps, a 3D surface visualization of the Xray map is shown. Transparency, plot style, and scaling can be altered.
- Additionally, by moving the cursor located on the image map, the window at the top right will show the spectrum associated with that XZ scan location.
- All plot windows in the front panel of this subVI contain reduced versions of the LabVIEW palette and cursor display for zooming and panning. (The unnecessary portions of the palette and cursor displays are covered with decorations the same color as the front panel to hide unnecessary functions.)
- The user has further options for changing image color scales, rebounding (contrast expanding or removing outliers) the image, and performing a channel averaging technique that reduces spectra noise and smoothes the resulting spectra and bin images. These options are enabled via mouse-clicking on the buttons in the lower left quadrant of the window. A collage of the overlying windows representing these options are shown in figure 6(b).
- The user, upon exiting, is given options to save the displayed image or entire front panel to .bmp, .jpg, or .png files. At this point, the user can also store the actual scan values (photon counts versus scan position) to a spreadsheet file. The user is then returned to the main calling window after exiting the subVI module.
- The user can view a movie (both in intensity graph and 3D surface format) of the Xray maps as a function of Xray bin number by selecting the control button on the main interface for this option.

Xray Life Testing System For Characterizing Degradation of Photon Detector Materials

The Xray Life Testing facility is used to measure performance over time for photon detector materials in various configurations/geometries (Parker, et al., 1999). The Life Test Facility consists of a maximum of 20 stations (5 substations with 4 detector samples each), and has provisions for measurement of temperature, power voltage, leakage current, and Xray spectrum for each station (although temperature measurement [thermocouple] and power voltage hardware are in place for each substation only [set of 4 samples] rather than for each station). A IEEE-488 (GPIB) controllable switching chassis system filled with multiplexing cards manages (under software supervision) the significant number of measurements required. Each multiplexing card has many "channels" and so can accommodate multiple measurements of a single type. The outputs of the measurements are then routed to GPIB-controlled multimeters (temperature, power voltage, leakage current) and a pc-resident multichannel analyzer

A/D card (Xray spectrum). (Temperature (type J thermocouple) and leakage current are routed to one multimeter and power voltage is routed to another). When the life test is started, radiation sources (Americium 241 isotope) bombard the photon detectors with radiation, and a voltage signal is generated across the sample related to the sample's charge carrier lifetime and mobility. The leakage current measurement for each sample is associated with the applied electric field and is calculated from the voltage drop across a resistor. A series of Xray spectra (number of photons as a function of spectral wavelength) for each sample are obtained after processing by a multichannel analyzer A/D card. The Xray spectras are then analyzed for eight different Xray parameters including Peak Counts Value, Gross Counts, and Full Width Half Max (%). A reference test pulse obtained from a pulser is used to determine whether Xray spectra or leakage current changes over time are real or are due to preamplification changes with time. The Full Width Half Max of the test pulse is recorded along with the other Xray parameters to allow the determination. The whole process is managed by the LabVIEW software. LabVIEW drivers were available for all of the instrumentation. Features include:

- The LabVIEW (v5.1.1) Xray life test software has a similar state machine type architecture as did the spectral mapping system, and the front panel (fig. 7) is organized similarly.
- Control buttons are disabled at various times so as to guide the user through the proper program operation.
- Management and setup of all the measurements is accomplished via a large, user-editable table control in the channel setup subVI module. An example with 16 measurements/channels is shown in figure 8. The table information is in ASCII text format and is initially recalled from a spreadsheet file. The table control is used to manage up to 80 different measurements in terms of (1) their associated parameters or characteristics (e.g., Xray integration time) and (2) their location within the hardware switching system. Since the information in the table is in ASCII text format, the values of parameters needed for further processing are converted to their numerical equivalent in the block diagram source code. At the bottom of the panel, a bitmap schematic is provided of the layout of one of the cards used for leakage current measurement so the user is shown how the physical connections on the card correspond to the channel numbers used for software control.
- The heart of this application is the actual life test subVI module. The life test can be setup to run for months. For the Life Test, the user has a number of choices regarding display modes for the actual life test. A dialog pop-up box appears with the choices of:
 - MAIN LIFE TEST WINDOW WITH NO CHARTING (fig. 9(a)): A significant number of parameters related to the life test are monitored on this window. At any point in the test, directly from this panel, the user can change Xray parameters such as integration time that were originally specified in the channel setup window. The changes take place when the next cycle of measurements begins. No on-screen history or trend charting of parameters is shown. Data in binary format is written to file.
 - LIFE TEST WITH 'SMALL' CHARTS: The window in figure 9(a) is shown and small charts that plot the various measurements/parameters are appended below the main panel (fig. 9(b)). The user employs the vertical scroll bar to get to this portion of the window. The charts utilized are the conventional LabVIEW waveform charts. Any combination of channels/stations data/measurements to display can be chosen via checkboxes (Gruggett, 1995a). Deselected channels are in fact still plotted but colored transparent. Whatever stations chosen will be applicable for all charts so that the checkbox control is global to all charts. The moving chart window will show the most current 50 measurements according to measurement number. Charts are updated after analysis of each cycle's data.
 - LIFE TEST WITH CHART HISTORIES (TRENDING): The window in figure 9(a) is shown along with individual pop-up chart history windows (fig. 9(c)). The chart history architecture is a modified, highly flexible version of that presented by Johnson, 1997. Significantly more control is available for the chart histories as compared to the conventional LabVIEW waveform chart that was utilized in figure 9(b). The chart histories show date and time on the x-axis; since the life test can go on for weeks or months, this scale is more informative than just a numbered measurement. The number of points to display in each chart history window is adjustable via the slider control near the top of each window; for the conventional waveform chart, it must be fixed in advance. The user can also scroll back in time to see early measurements that are not currently in the window when the number of points shown in the window is less than the total number of samples stored for chart history. Once data has been collected beyond the number of samples to store for chart history is obtained, the earliest data is flushed from the (circular) buffer (Johnson, 1997 and LabVIEW Developer Zone, 2000). Any combination of channels (measurement) can be chosen via checkboxes for each individual chart history window. The charting can be paused. A large 'chart' mode is available via control button on each individual panel. The truly individual nature of each chart history was managed by

making brother copies of a master chart history VI in the source code prior to execution. A more elegant and feasible solution would have been to dynamically make copies of the master chart during program execution based on the number of properties chosen to chart. Chart histories are updated after analysis of each cycle's data. However, the chart histories cannot be scrolled while Xray data is being taken since the Xray control involves synchronous Dynamic Data Exchange calls that monopolize CPU time.

- Data originally stored in binary format can be converted to ASCII text format for storage in spreadsheet format via a main interface control button. The data can then be read by software programs such as Microsoft Excel.
- A simulation mode is present to test new features off-line (without hardware attached) and to demonstrate facility operation to visitors.

The New Cloud Absorption Radiometer

The aircraft-mounted Cloud Absorption Radiometer (CAR) instrument has been the most frequently used airborne instrument built in-house at NASA Goddard Space Flight Center. Since 1983, it has been used to gather data for atmospheric studies over many sites in the United States, Azores, Brazil, and Kuwait (King, et al., 1986 and King, 1992). The CAR instrument is capable of measuring light scattered by clouds in fourteen spectral bands in ultraviolet, visible and near-infrared regions (total wavelength range of 0.340 to 2.3 μm). CAR data has been the basis for climate studies, remote sensing application development, and atmospheric condition assessment (e.g., after disasters such as the Kuwaiti oil fires). The LabVIEW (v5.1.1) software interface for CAR (fig. 10) completely replaces the prior data system and control panel with a compact and robust virtual instrument that performs control, data acquisition, display, and data storage functions.

Some of the software features and operation details include:

- The CAR interface is logically divided into control buttons, status indicators, and data display functions.
- A full data cycle consisting of 10308 character bytes of data from two RS-422 serial ports is acquired, decoded, analyzed, displayed, and stored every 600 msec. Typical mission experiments run for 2 to 4 hours resulting in 100-200 mb data sets. One serial port reads 10264 character bytes obtained from the instrument controller. This is the instrument data. A second serial port obtains aircraft information such as latitude, longitude, altitude, pitch and roll angles from a transmission every 100 msec by the University of Washington. The aircraft data is needed to understand the state of the aircraft while the instrument obtains its radiometric data. The two data streams are concatenated at the end of each data cycle, and correlated with each other during post-flight analysis. Each cycle's data is written to file on hard disk for post-processing.
- Serial port writes are used to send commands to the controller module of the instrument. The commands written (when the user interacts with one of the control buttons on the CAR software interface) are converted to analog voltages to control the various hardware functions such as mirror heating.
- Two main while loops controlling the serial communication are employed in the source code: one controlling serial command writes and one controlling serial data reads. The while loops operate at different speeds (delays). Communication between the two while loops is accomplished via local variables.
 - The loop controlling serial command writes is in a wait state (polling occurs every 100 msec) until triggered by one of the commands (e.g., change of Dwell Setting).
 - The loop controlling serial data reads checks for the predefined number of character bytes (representing a whole data cycle's worth of information) to have arrived at the serial port before executing the remaining decoding and display functions. If the predefined number of bytes has not arrived at the read serial port, the loop waits until the next 5 msec multiple (plus 1 extra msec) before checking again. This architecture is based on that shown for conventional serial communication function presented in Johnson, 1999.
- LabVIEW v2.5 VISA serial functions are employed seamlessly for serial port communication.
- Empirical demonstrations revealed that the MS Windows NT 4.0 operating system executed the LabVIEW software significantly faster than MS Windows 98. Special LabVIEW routines are required to access the parallel port when using the Windows NT operating system.

- A command written to the computer parallel port from the software interface is used to start the instrument via an isolated switching interface device on the instrument.
- Control button and indicator colors 'red' and 'green' are utilized consistently in the interface to indicate inactive/off and active/on states. Controls are enabled and disabled based on user actions to guide the user through virtual instrument operation. Function and nonfunction key navigation (with special LabVIEW keyboard utility for the latter) is employed for controls.
- Real-time plotting of data from any combination of user-selectable spectral channels/bands at any user-selectable view angle (based on the tilt of the aircraft) is utilized.
- Lower CAR Data graph utilizes circular buffer technique (Johnson, 1997 and LabVIEW Developer Zone, 2000) to manage viewing of latest 100 cycles of data.
- The instrument has been software-enabled to work in an off-aircraft mode that allows calibration, testing, and experimentation prior to the mission.
- A simulator mode is available that allows pre-testing of new features that might be added in the future. This mode also permits development at times when the instrument/hardware is off-location, and demonstrations to visitors interested in the CAR. The simulator mode uses no serial port hardware to operate; only global variables written to and read from.
- Preliminary data from the August 2000 CAR mission flown over S. Africa and utilizing the new CAR version for the first time is publicly available at <http://www.safari2000.org>. Additional information for CAR projects are available at <http://car.gsfc.nasa.gov>. (These were the website addresses at time of publication.)

CONCLUSION

This article provided an overview of several software control applications developed for NASA using LabVIEW. The applications covered here included:

- an Ultrasonic Measurement System for nondestructive evaluation of advanced structural materials, an X-ray Spectral Mapping System for characterizing the quality and uniformity of developing photon detector materials
- a Life Testing System for these same materials,
- and the instrument panel for an aircraft-mounted Cloud Absorption Radiometer that measures the light scattered by clouds in multiple spectral bands.

Current applications written in LabVIEW v6i and later will make extensive use of custom run-time menu-based and tab control-based interfaces in concert with state machines. The implementation of those applications will be presented in future articles.

REFERENCES

- Bitter, R., Mohiuddin, T., and Nawrocki, M., LabVIEW Advanced Programming Techniques, Chapter 3, "State Machines," CRC Press, 2001.
- Baroth, E. and Wells, G., Chapter 11, "Data Acquisition From Space via the Internet," LabVIEW Power Programming, edited by G. Johnson, McGraw-Hill, 1998.
- Buchanan, R.K., Coleman, B., and Ludwig, L., "Interfacing LabVIEW With Instrumentation for Electronic Failure Analysis and Beyond," Document ID: 19970006836 N (97N13729). File Series: NASA Technical Reports, 1996.
- Fowler, Gregg, "Interactive Architectures Revisited," LabVIEW Technical Resource, Vol. 4, No. 2, 1996, pp. 12–15.
- Gruggett, Lynda, "A Fast Way to Add and Remove Plots from a Multiplot," LabVIEW Technical Resource, Vol. 3, No. 4, 1995a, p. 13.
- Gruggett, Lynda, "State Your Case!," LabVIEW Technical Resource, Vol. 3, No. 1, 1995b, pp. 12–14.
- Huff, M.R., "A LabVIEW Based Wind Tunnel Data Acquisition System," Document ID: 19990008879 File Series: NASA Technical Reports, Report Number: AD-A355656, 1998.
- Johnson, Gary W., Labview Graphical Programming, 2nd Edition, McGraw-Hill, 1997, pp. 192–196, 201–205, 482–483, 493–496.

- Johnson, Rande, "Rules to Wire By (VI Development Techniques)," LabVIEW Technical Resource, Vol. 7, No. 2, 1999, p. 4.
- King, Michael D., Strange, Maxwell G., Leone, P., and Blaine, Lambdin, R., Multiwavelength Scanning Radiometer for Airborne Measurements of Scattered Radiation within Clouds, *Journal of Atmospheric and Oceanic Technology*, Vol. 3, No. 3, September 1986, pp. 513–522.
- King, Michael D., Directional and Spectral Reflectance of the Kuwait Oil-Fire Smoke, *Journal of Geophysical Research*, vol. 97, no. D13, Sept. 20, 1992, pp. 14,545–14,549.
- Lhota, J.R., "Modeling and Simulating Ultrasonic Wave Propagation in Layered Structures," Document ID: 19980202658 File Series: NASA Technical Reports, Report Number: AD-A341045 TR-96(8565)-8 SMC-TR-98-05, 1998.
- "LabVIEW Style Guide," Chapter 6, LabVIEW Development Guidelines, National Instruments, July, 2000.
- National Instruments Developer Zone, "Retaining the 150 Most Recent Values in an Array," 2000.
- Parker, B.H., Stahle, C.M., Barthelmy, S.D., Parsons, A.M., Tueller, J., Van Sant, J.T., Munoz, B., Snodgrass, S.J., and Mullinax, R.E., "Correlation Between bulk material defects and spectroscopic response in cadmium zinc telluride detectors," *Hard X-ray, Gamma-Ray, and Neutron Detector Physics*, R.B. James, R.C. Schirato, Volume 3768, SPIE-the International Society for Optical Engineering, Bellingham, WA, 1999.
- Roth, D.J., et al., "Quantitative Mapping of Pore Fraction Variations in Silicon Nitride Using an Ultrasonic Contact Scan Method," NASA TM-3377 and in Vol. 6, No. 3, 1995 *Research in Nondestructive Evaluation*. Also see: <http://LeTRS.lerc.nasa.gov/cgi-bin/LeTRS/browse.pl?1993/TP-3377.html>.
- Wilson, T.M., "Development of a Multi-Channel Integration Routine in LabVIEW" Report Number: AD-A331651 ERDEC-CR-237 Document ID: 19980010903 File Series: NASA Technical Reports. 1997.
- <http://www.safari2000.org> (website address at time of publication)
- <http://www.ni.com>
- <http://car.gsfc.nasa.gov> (website address at time of publication)

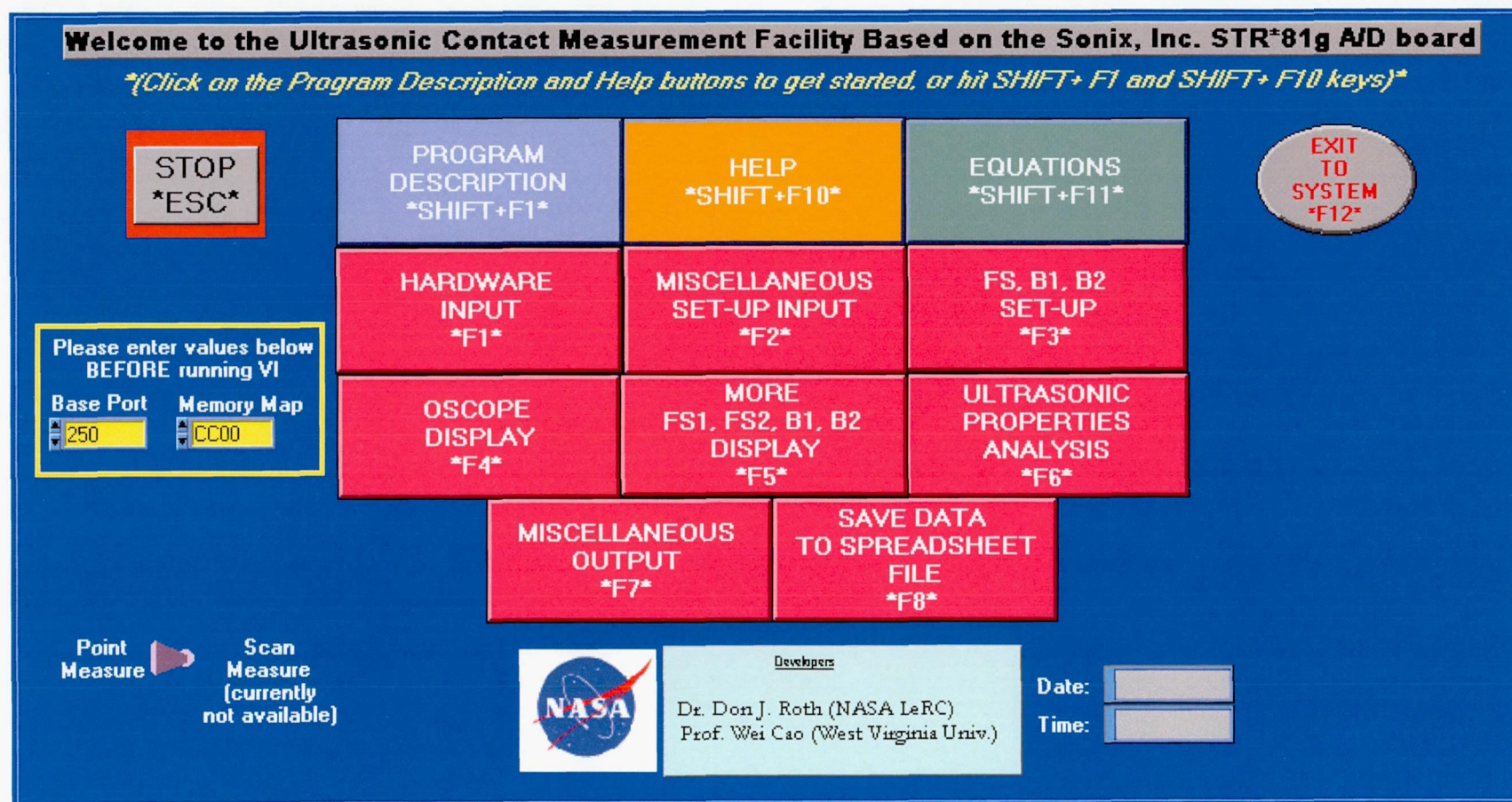


Fig. 1. Ultrasonic Measurement Software main interface.

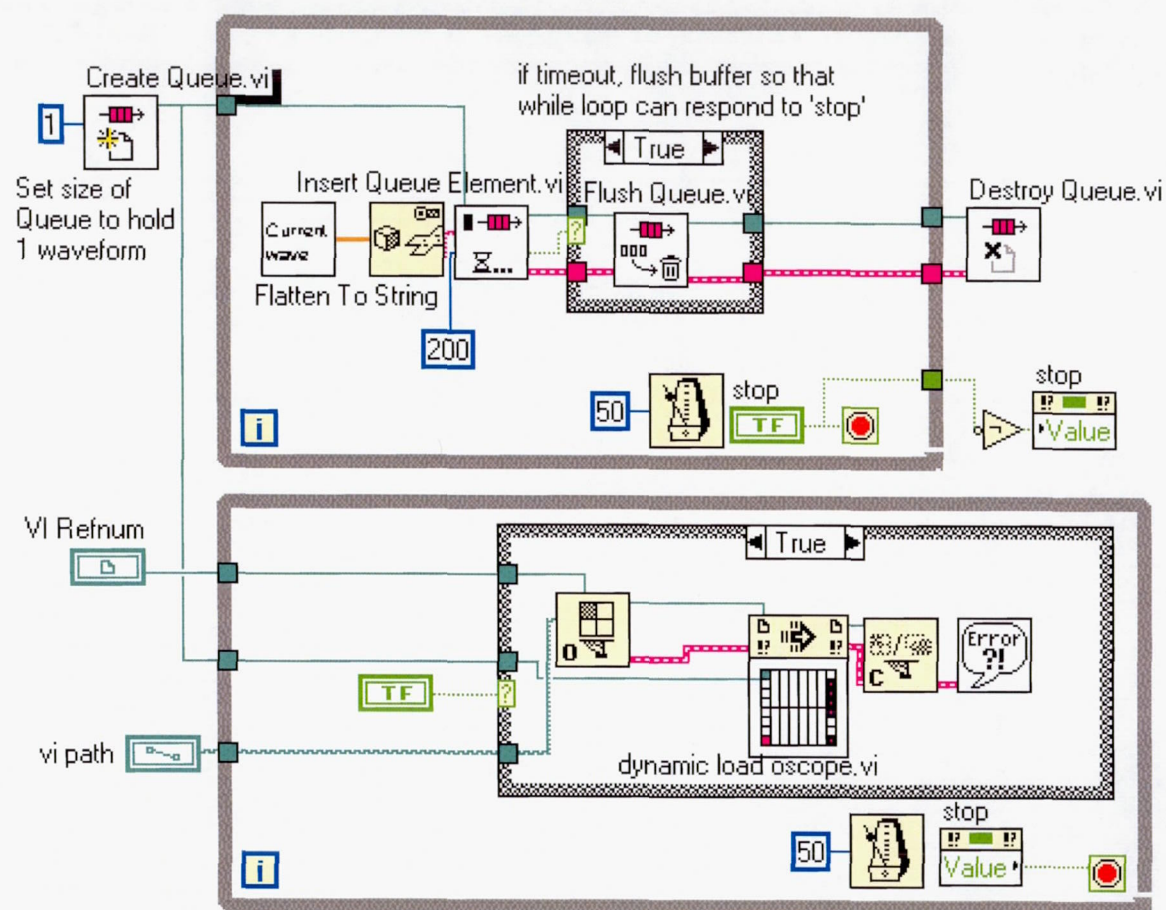


Fig. 2. Model of Block Diagram Source Code for Ultrasonic Measurement Software.

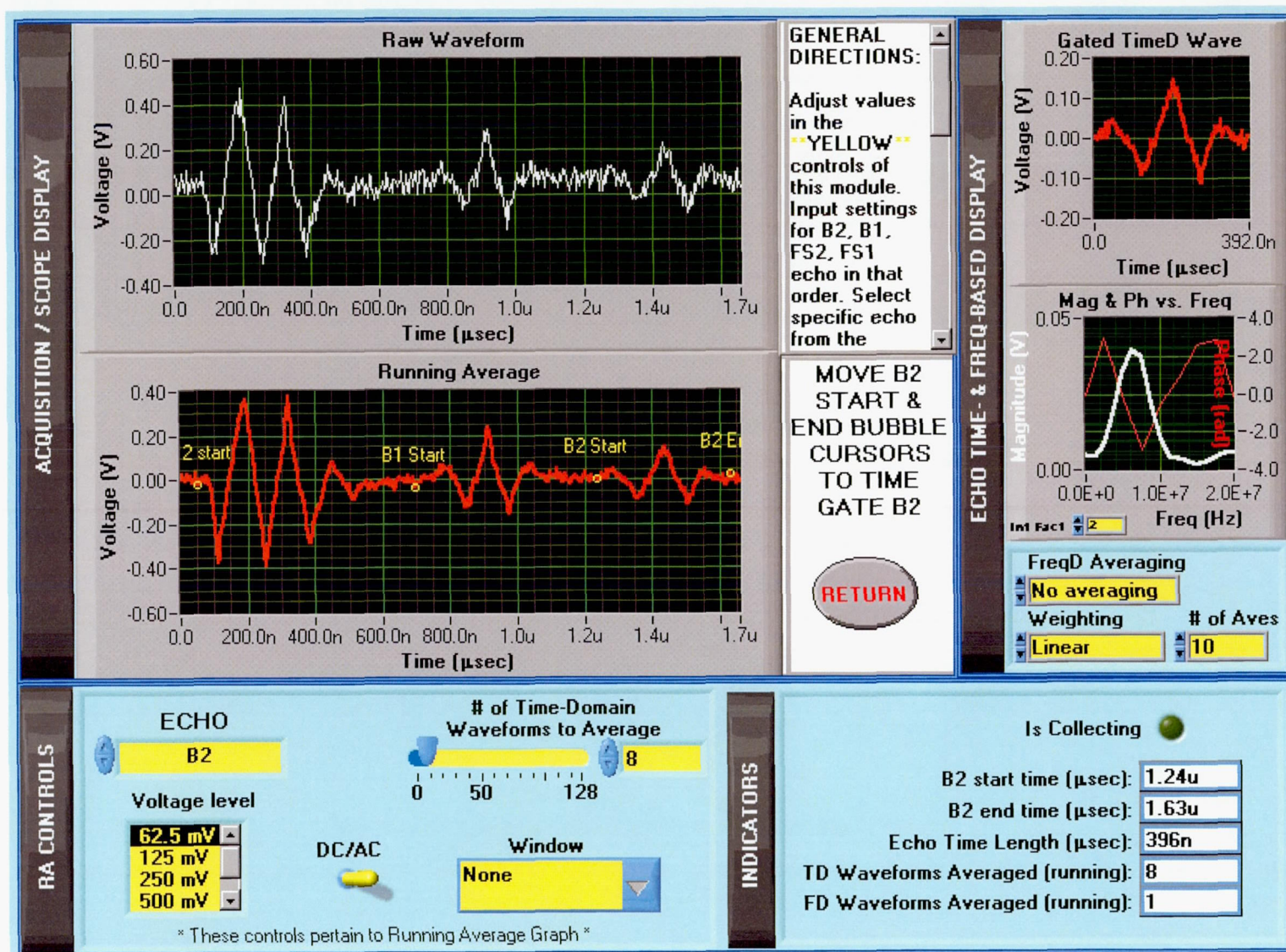


Fig. 3. Front Panel for Oscilloscope SubVI Module in Ultrasonic Measurement Software.

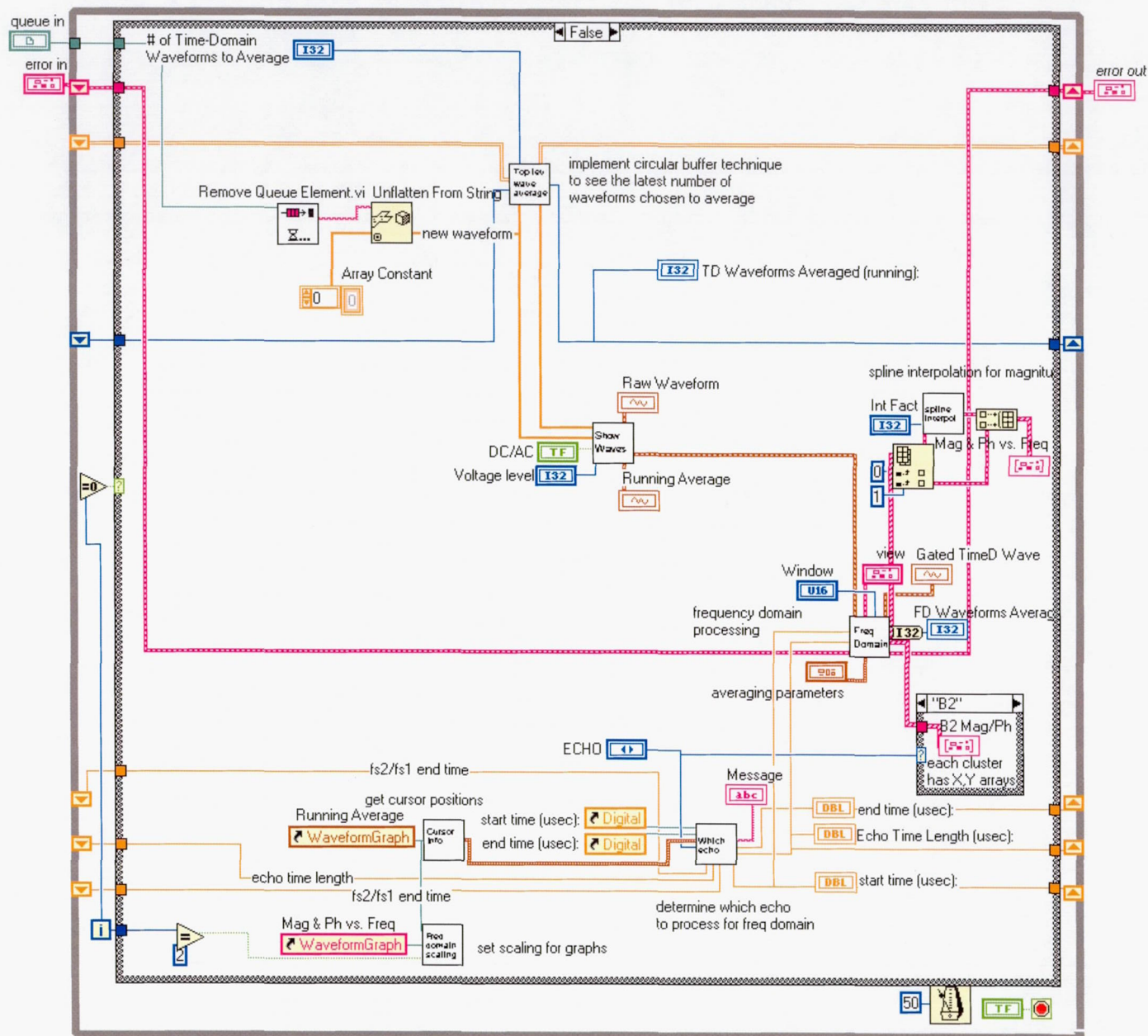


Fig. 4. Block Diagram Source Code for Oscope SubVI Module in Ultrasonic Measurement software. Initialization case ($I = 0$) is not shown.

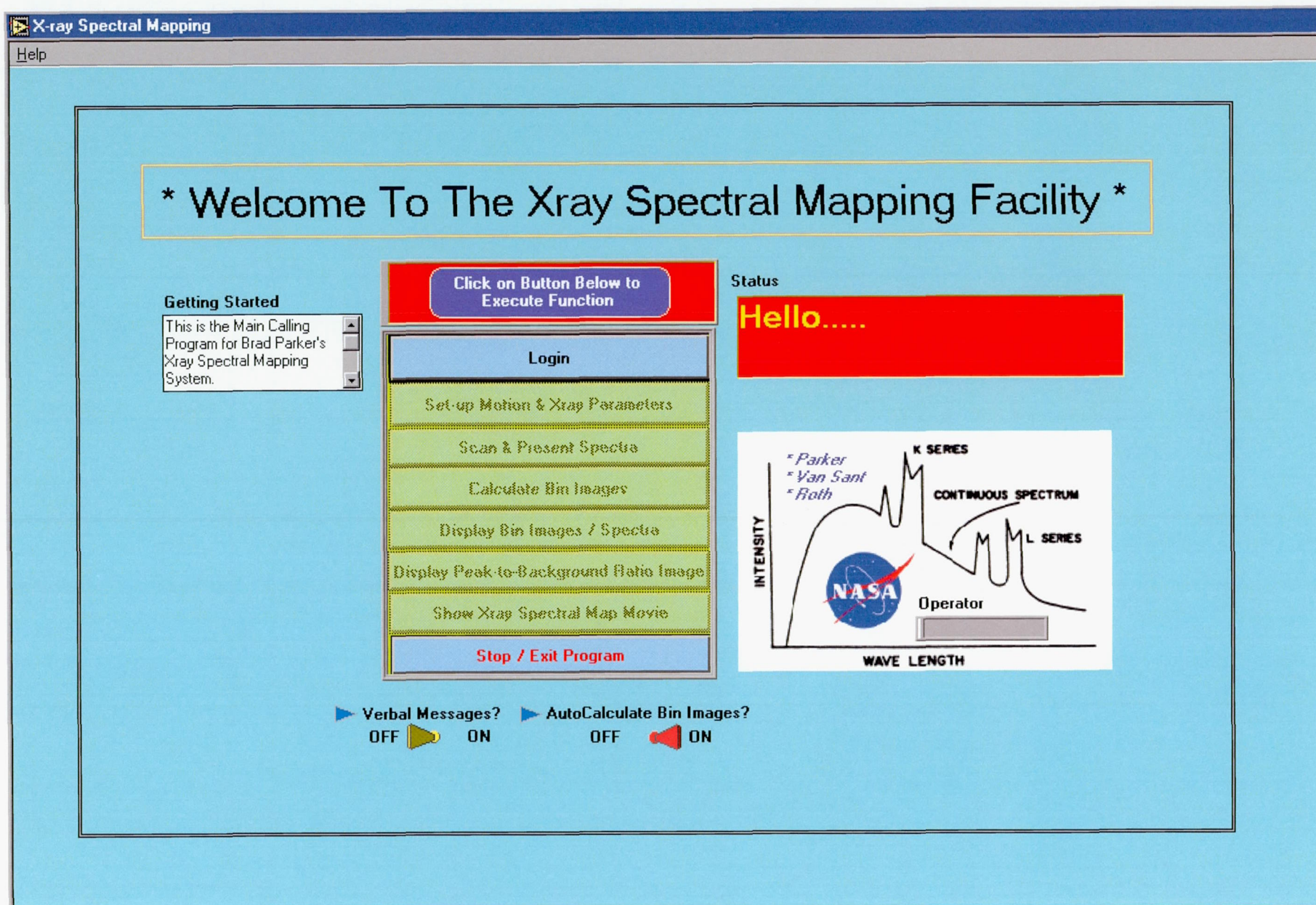


Fig. 5. Main Interface for Xray Spectral Mapping Facility.

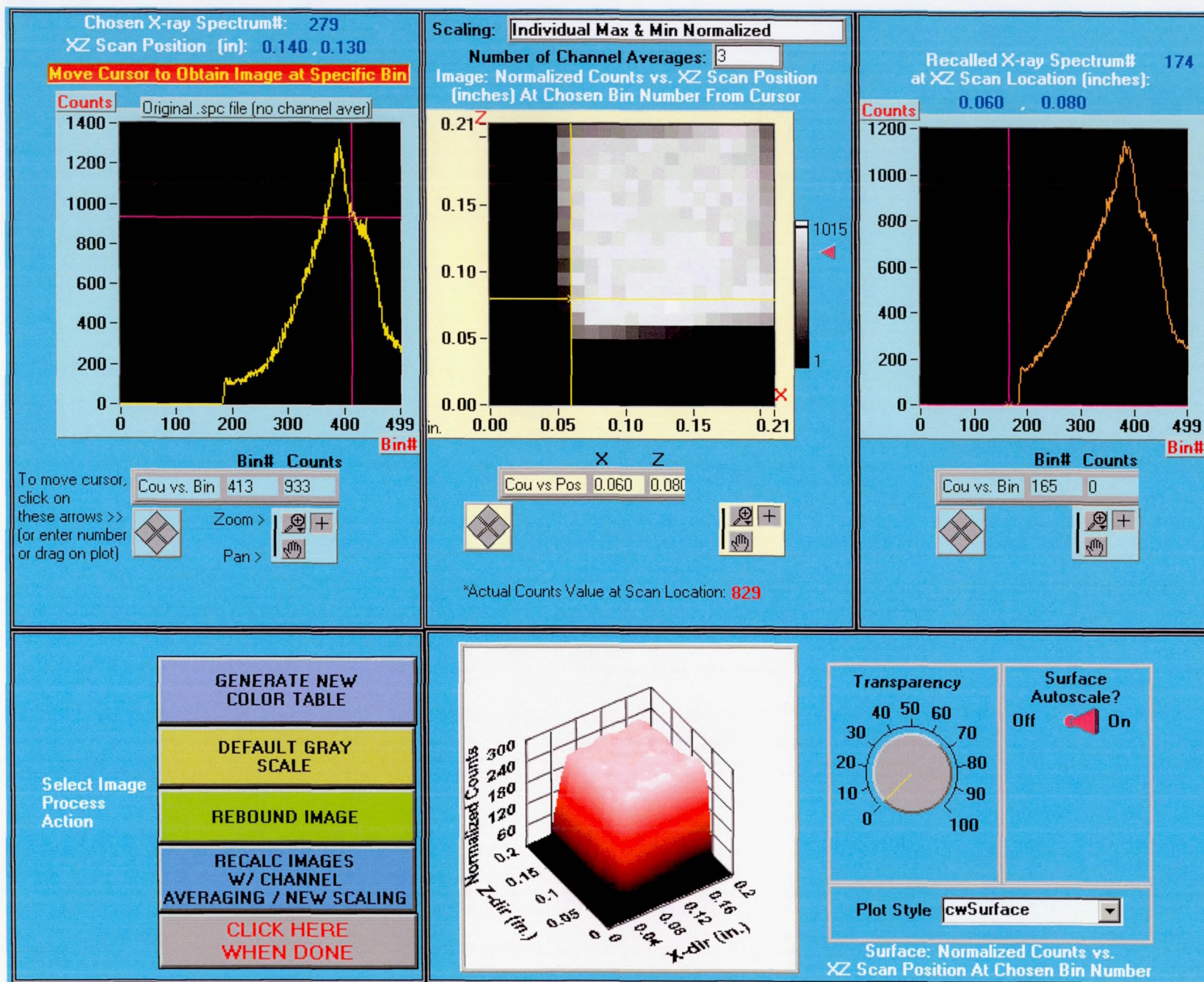
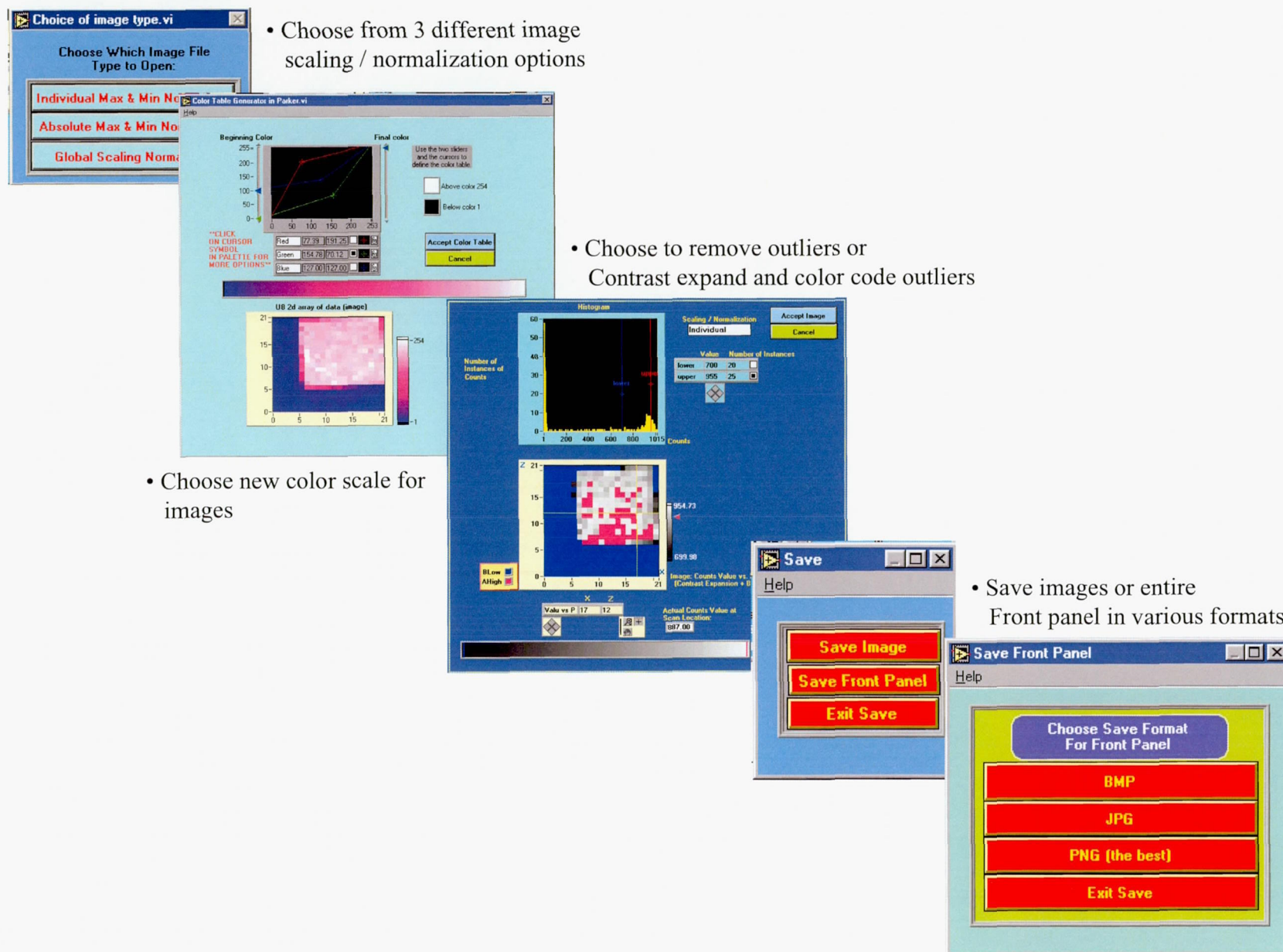


Fig. 6a. Window that Displays Images and Spectra from Xray Spectral Mapping Test.



- Choose from 3 different image scaling / normalization options

- Choose to remove outliers or Contrast expand and color code outliers

- Choose new color scale for images

- Save images or entire Front panel in various formats

Fig. 6b. SubWindows available from the panel shown in fig. 6a.

* Welcome To The Xray Spectral Life Test Facility *

Getting Started

This is the Main Calling Program for Brad Parker's Xray Spectral Life Test Facility.

Test Mode

Simulation  Actual

AutoStep Thru Program?
(applicable 1st time thru)

No  Yes

Click on Button Below to Execute Function

Configure / Edit Channels*

General Experimental Setup Parameters

System Communication Test

Run Life Test

Binary File --> Text File

Post Life Test Plotting

Stop / Exit Program

* Note: It is easier to perform large-scale editing of configuration file in spreadsheet program

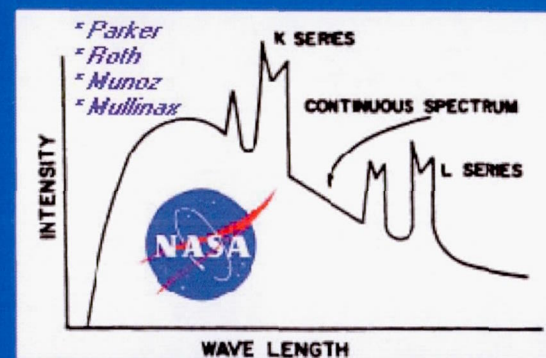
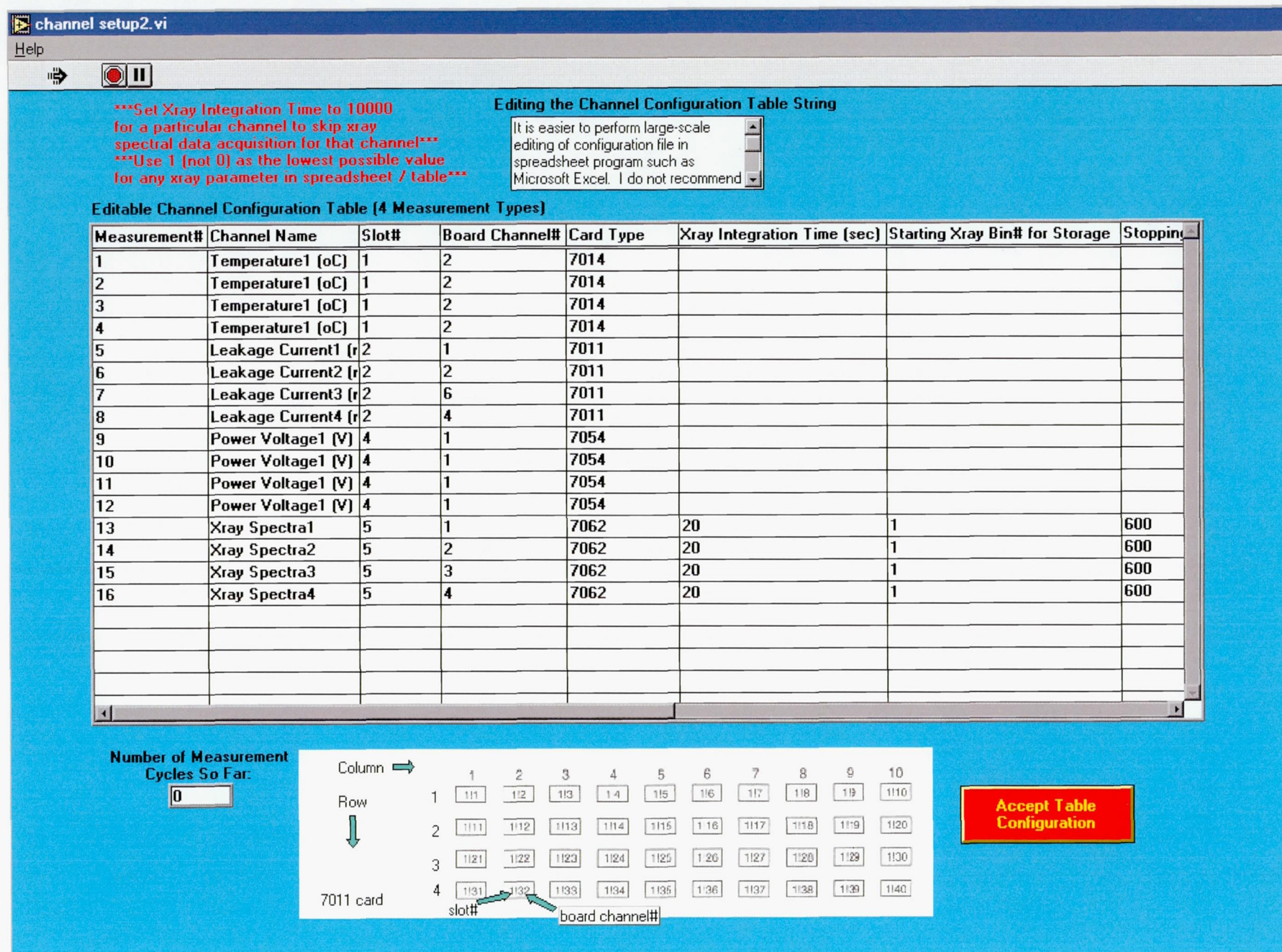


Fig. 7. Xray Spectral Life Test Facility Main Interface.



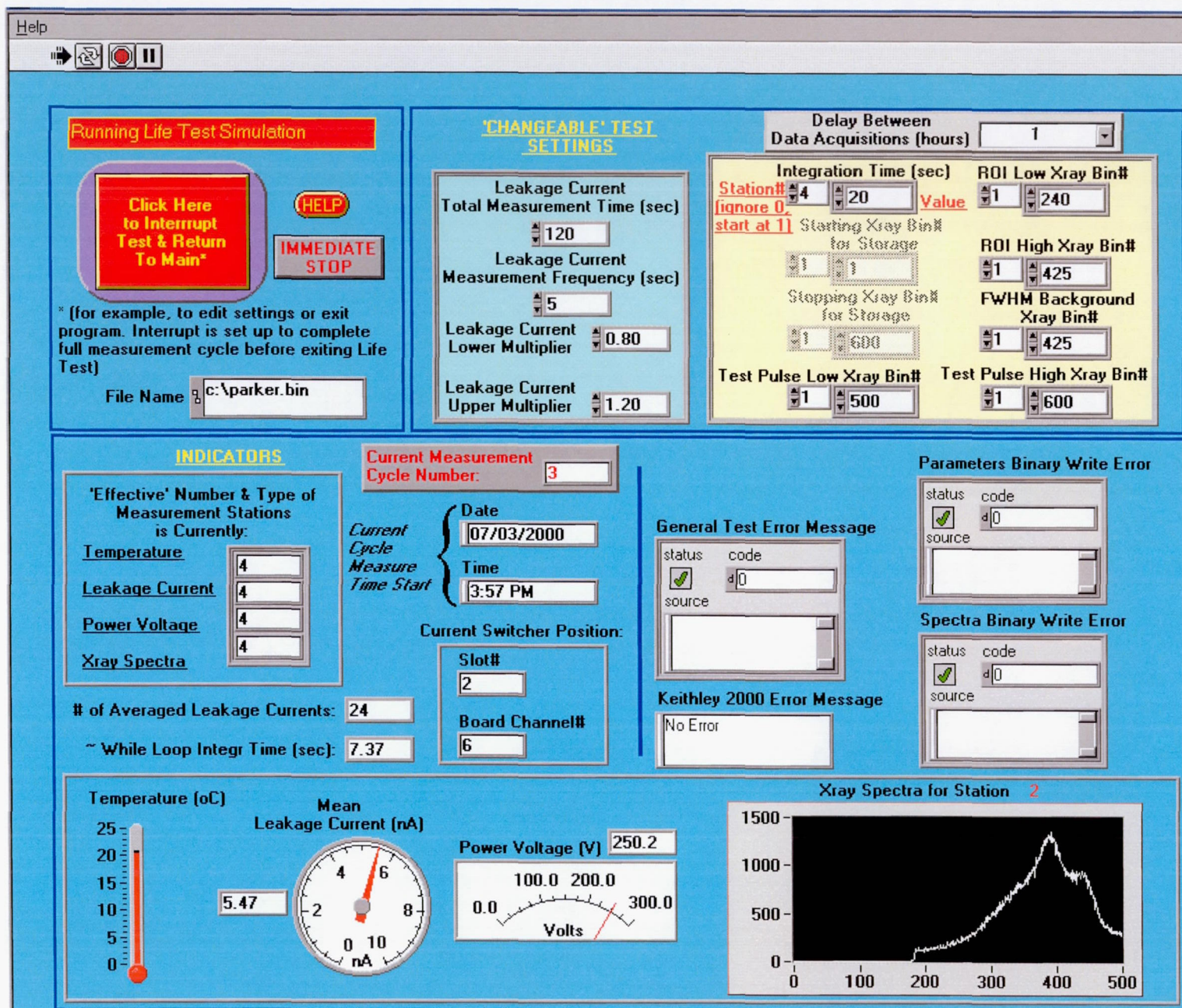


Fig. 9a. Life Test Window.

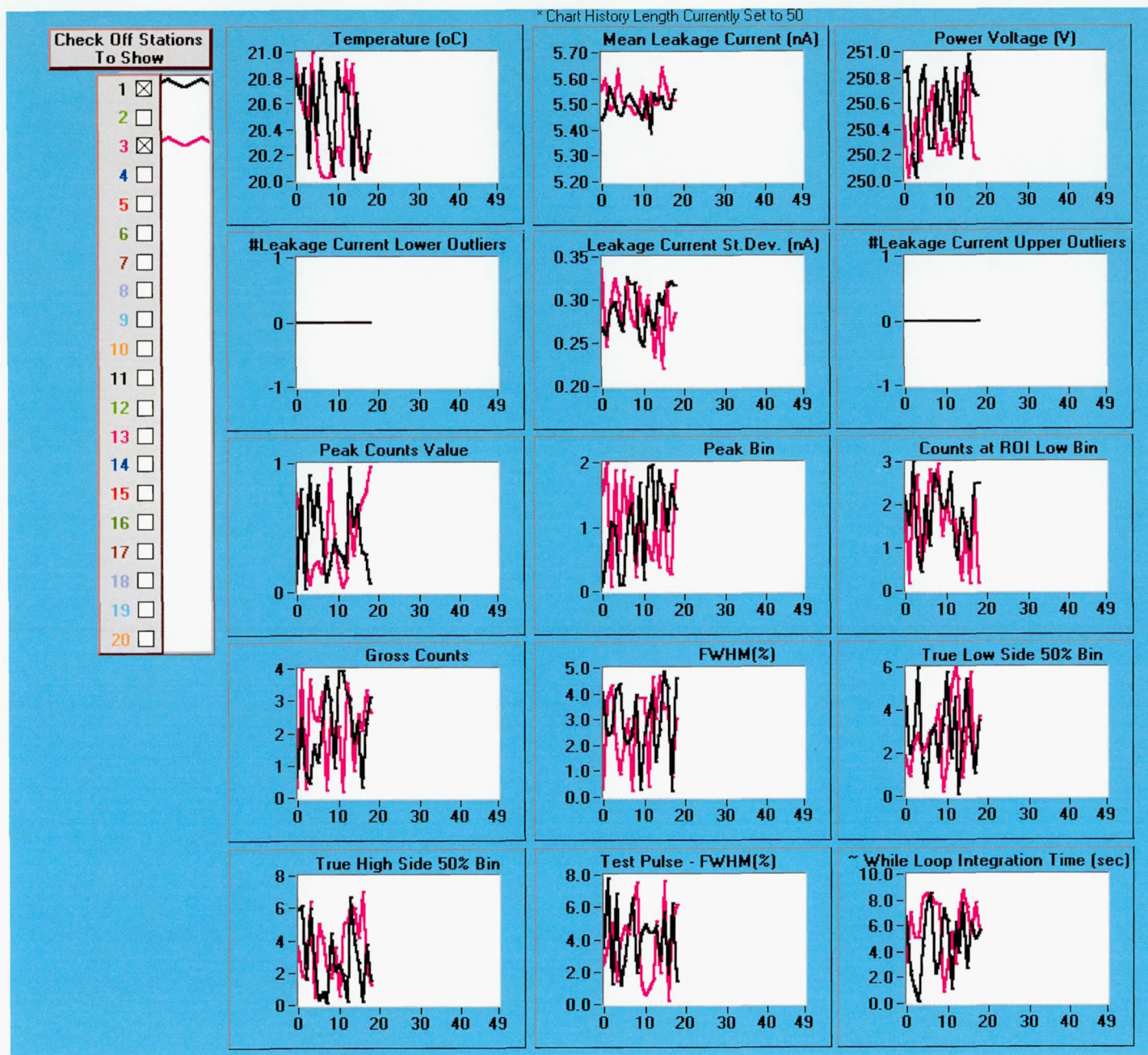


Fig. 9b. Portion of Life Test Window With 'Small' Charts. Appendage of window in fig. 9b if user chooses to show these.

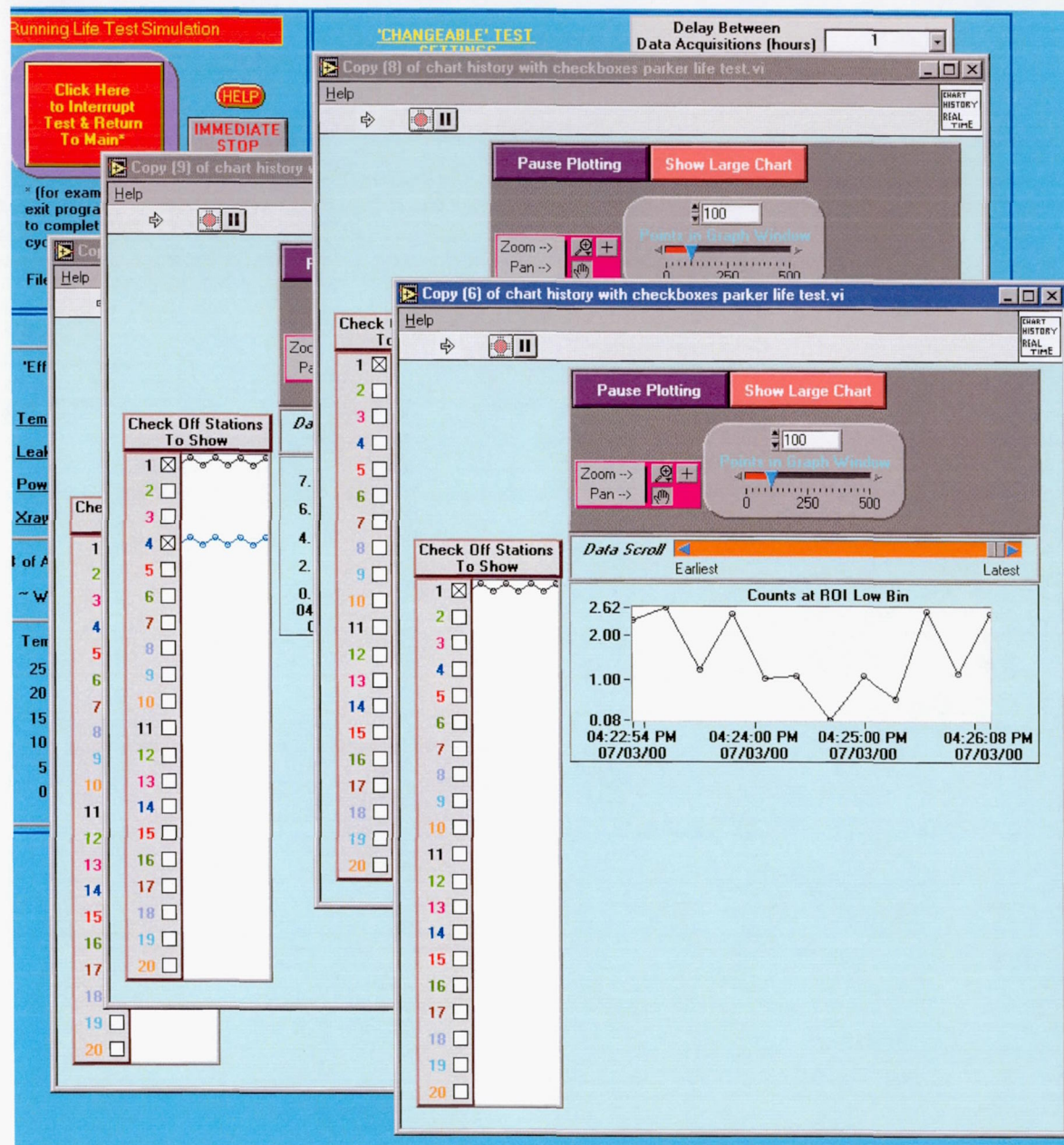


Fig. 9c. Life Test With Chart Histories.

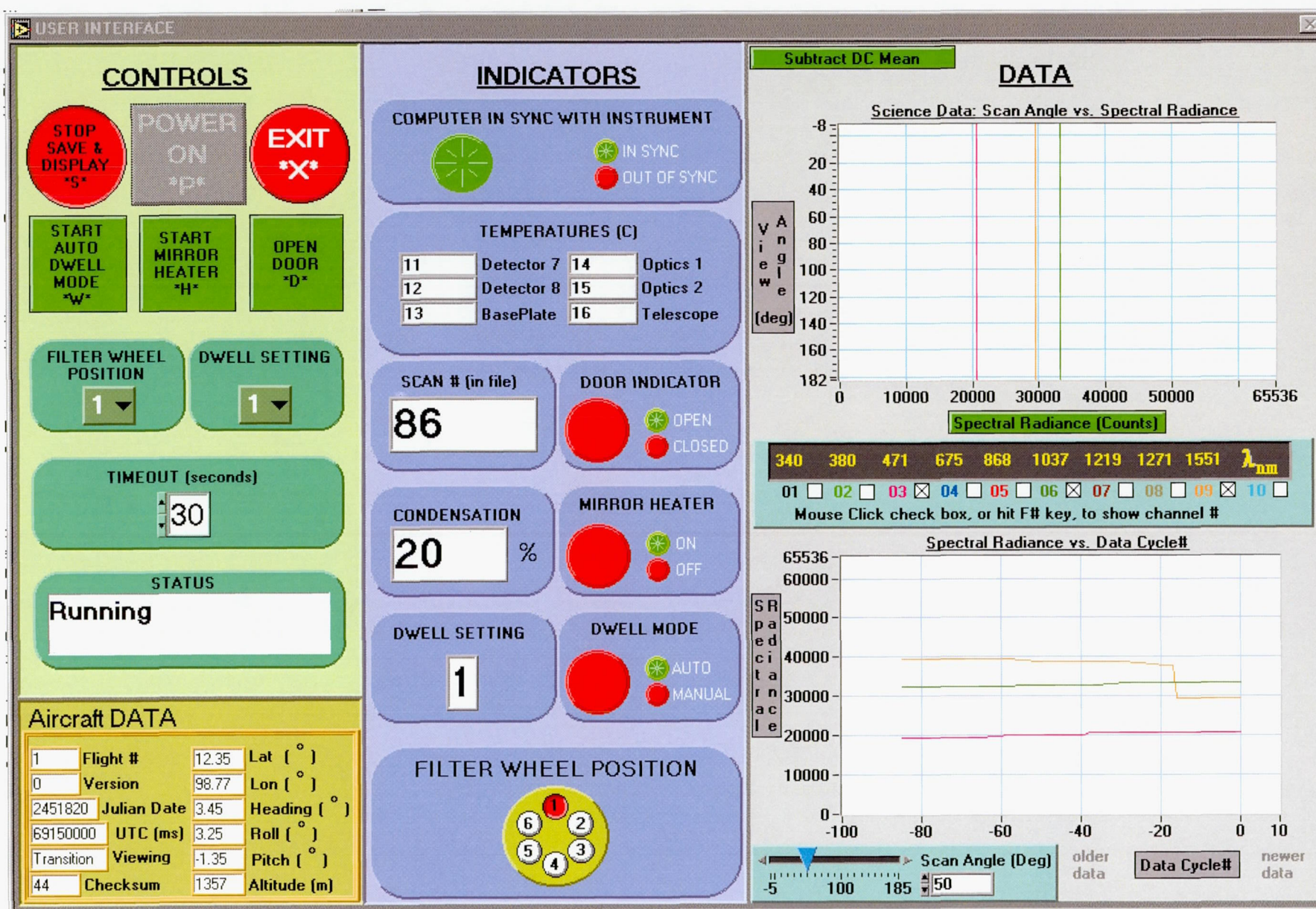


Fig. 10. The Cloud Absorption Radiometer Interface.

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13. ABSTRACT (Maximum 200 words) This article provides an overview of several software control applications developed for NASA using LabVIEW. The applications covered here include (1) an Ultrasonic Measurement System for nondestructive evaluation of advanced structural materials, an Xray Spectral Mapping System for characterizing the quality and uniformity of developing photon detector materials, (2) a Life Testing System for these same materials, (3) and the instrument panel for an aircraft-mounted Cloud Absorption Radiometer that measures the light scattered by clouds in multiple spectral bands. Many of the software interface concepts employed are explained. Panel layout and block diagram (code) strategies for each application are described. In particular, some of the more unique features of the applications' interfaces and source code are highlighted. This article assumes that the reader has a beginner-to-intermediate understanding of LabVIEW methods.				
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